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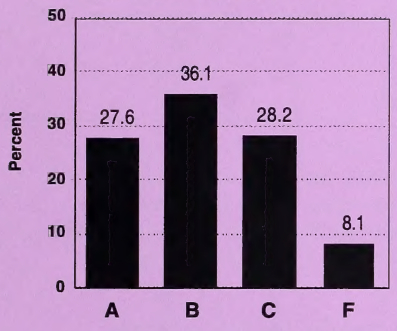
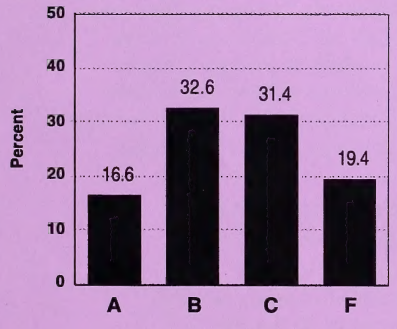
# Chemistry 30

## Diploma Examination Results
## Examiners' Report for June 1996

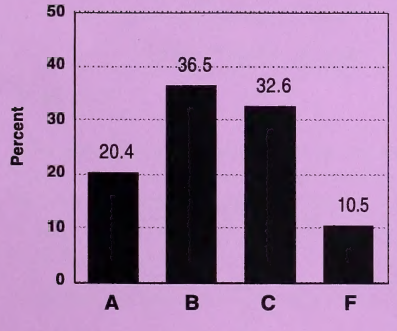
**School-Awarded Mark**




**Diploma Examination Mark**




**Final Course Mark**




The summary information in this report provides teachers, school administrators, students, and the general public with an overview of results from the June 1996 administration of the Chemistry 30 Diploma Examination. This information is most helpful when used with the detailed school and jurisdiction reports that have been mailed to schools and school jurisdiction offices. An annual provincial report containing a detailed analysis of the combined January, June, and August results is published each year.

### *Description of the Examination*

The Chemistry 30 Diploma Examination consists of 44 multiple-choice questions worth 55%, 12 numerical-response questions worth 15%, and 2 written-response questions worth 30% of the total examination mark.

### *Achievement of Standards*

The information reported is based on the final course marks achieved by 8 225 students in Alberta who wrote the June 1996 examination. This represents an increase of 119 compared with June 1995.

- 89.5% of the 8 225 students achieved the acceptable standard (a final course mark of 50% or higher).
- 20.4% of these students achieved the standard of excellence (a final course mark of 80% or higher).

Overall, student achievement in Chemistry 30 was acceptable, particularly in knowledge of core concepts. However, students had difficulty with applying equilibrium concepts to buffers, and in organizing and communicating their chemistry knowledge.

Approximately 51.6% of the students who wrote this examination were female, which is similar to the percentage of females in the population at this age group. The acceptable standard in the course was achieved by approximately 90.0% of this female population, compared with 88.9% of the male population. Approximately 19.6% of the female population achieved the standard of excellence in the course, compared with 21.4% of the male population.

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### *Provincial Averages*

- The average school-awarded mark was 69.2%.
- The average diploma examination mark was 63.3%.
- The average final course mark, representing an equal weighting of the school-awarded mark and the diploma examination mark, was 66.6%.

Approximately 9.4% of the students who wrote the examination in June 1996 and received a school-awarded mark had written at least one other Chemistry 30 Diploma Examination during the January 1994 to January 1995 period. This sub-population (774) did not do as well (58.6%) as the population (7451) who first wrote a Chemistry 30 examination (63.8%) in June 1996. However, the group of students who rewrote the chemistry examination increased their score, on average, 7.8%.

## *Results and Examiners' Comments*

This examination has a balance of question types and difficulties. It is designed so that students achieving the acceptable standard will obtain a mark of 50% or higher, and students achieving the standard of excellence will obtain a mark of 80% or higher. Future examinations will continue to require students to demonstrate clarity in their thinking and an understanding of concepts by applying their knowledge to new and novel situations. Students will also continue to be required to present their answers in a clear, concise, organized fashion and to respect the conventions of the mode of communication selected. Those who achieved these expectations were successful in this examination.

In the following table, diploma examination questions are classified by question type: multiple choice (MC), numerical response (NR), and written response (WR). The column labelled "Key" indicates the correct response for multiple-choice and numerical-response questions. For numerical-response questions, a limited range of answers was accepted as being equivalent to the correct answer.

For multiple-choice and numerical-response questions, the difficulty indicates the proportion (out of 1) of students answering the question correctly. For written-response questions, the difficulty is the mean score achieved by students who wrote the examination.

Questions are also classified by general learner expectations.

**Knowledge:**

- GLE 1 Quantitatively Predicting Outcomes
- GLE 2 Qualitatively Analyzing Systems
- GLE 3 Relationships in Energy Transfer
- GLE 4 Relationships in Electron Transfer
- GLE 5 Relationships in Equilibrium Systems
- GLE 6 Relationships in Proton Transfer

**Skills:**

- SPSC Scientific Process Skills and Communication Skills

**Science, Technology, Society:**

- STS Connections Among Science, Technology, & Society

***Blueprint***

| Question | Key | Difficulty | GLE 1 | GLE 2 | GLE 3 | GLE 4 | GLE 5 | GLE 6 | SPSC | STS |
|---|---|---|---|---|---|---|---|---|---|---|
| MC 1 | C | 0.854 | | √ | √ | | | | | |
| NR 1 | 2345 | 0.754 | √ | | √ | | | | √ | |
| MC 2 | D | 0.617 | | √ | √ | | | | | √ |
| MC 3 | D | 0.620 | √ | | √ | | | | √ | √ |
| NR 2 | 10.4 | 0.758 | √ | | √ | | | | √ | √ |
| MC 4 | D | 0.680 | | √ | √ | | | | | √ |
| NR 3 | * | 0.634 | √ | | √ | | | | √ | √ |
| MC 5 | A | 0.462 | | √ | √ | | | | | √ |
| MC 6 | D | 0.877 | | √ | √ | | | | | |
| MC 7 | B | 0.747 | | √ | √ | | | | | |
| MC 8 | C | 0.718 | | √ | √ | | | | √ | |
| MC 9 | C | 0.504 | √ | | √ | | | | √ | |
| MC 10 | C | 0.829 | √ | | √ | | | | √ | |
| MC 11 | A | 0.773 | √ | | √ | | | | √ | |
| MC 12 | A | 0.737 | | √ | √ | | | | | |

| Question | Key | Difficulty | GLE 1 | GLE 2 | GLE 3 | GLE 4 | GLE 5 | GLE 6 | SPSC | STS |
|---|---|---|---|---|---|---|---|---|---|---|
| MC 13 | A | 0.822 | √ | | √ | | | | | √ |
| MC 14 | D | 0.567 | | √ | √ | | √ | | √ | |
| MC 15 | B | 0.810 | √ | | √ | | | | √ | √ |
| MC 16 | A | 0.681 | √ | | √ | | | | √ | √ |
| MC 17 | A | 0.500 | | √ | | √ | | | | √ |
| MC 18 | C | 0.597 | | √ | √ | √ | √ | | | √ |
| MC 19 | B | 0.789 | √ | | | | √ | √ | √ | √ |
| MC 20 | D | 0.664 | | √ | | √ | | | | √ |
| MC 21 | C | 0.406 | | √ | | | √ | √ | | √ |
| MC 22 | B | 0.637 | √ | | | | √ | | √ | √ |
| MC 23 | B | 0.491 | | √ | | | √ | √ | | √ |
| MC 24 | A | 0.551 | | √ | | √ | | | √ | √ |
| NR 4 | ** | 0.191 | √ | | | √ | | √ | √ | |
| MC 25 | A | 0.831 | √ | | | √ | | √ | | √ |
| NR 5 | 2.93 | 0.454 | √ | | | √ | | | √ | √ |
| NR 6 | *** | 0.456 | √ | | | √ | | √ | √ | √ |
| MC 26 | A | 0.606 | √ | | | √ | | | | √ |
| MC 27 | B | 0.889 | √ | | | | | √ | √ | √ |
| MC 28 | D | 0.659 | | √ | | √ | | | | √ |
| MC 29 | B | 0.609 | | √ | | √ | | | | √ |
| NR 7 | 36.5 | 0.172 | √ | | √ | √ | | | √ | √ |
| MC 30 | A | 0.571 | | √ | | √ | | | | |
| MC 31 | D | 0.859 | | √ | | √ | | | | |
| MC 32 | C | 0.713 | | √ | | √ | | | √ | |
| NR 8 | 2341 | 0.512 | | √ | | √ | | | √ | |
| MC 33 | D | 0.387 | | √ | | √ | | | | √ |
| NR 9 | 1.31 | 0.410 | √ | | | √ | | | √ | √ |
| MC 34 | C | 0.885 | √ | | | | | √ | | √ |
| MC 35 | C | 0.857 | | √ | | √ | | | √ | √ |
| MC 36 | B | 0.700 | | √ | | | √ | √ | | √ |
| MC 37 | D | 0.472 | | √ | | | √ | | | |
| MC 38 | D | 0.770 | | √ | | | √ | | | |
| MC 39 | B | 0.843 | | √ | | | | | | |
| MC 40 | A | 0.766 | | √ | | | | √ | | |
| NR 10 | 1245**** | 0.753 | | √ | | | | √ | | |
| MC 41 | D | 0.816 | | √ | | | | √ | | √ |
| MC 42 | C | 0.760 | √ | | | | | √ | √ | |
| NR 11 | 1243 | 0.779 | √ | | | | √ | √ | | √ |
| MC 43 | A | 0.829 | | √ | | | √ | √ | √ | |
| NR 12 | 7.32 | 0.110 | √ | | | | √ | √ | √ | √ |
| MC 44 | C | 0.647 | | √ | | | √ | √ | | √ |
| WR 1 | — | 0.615 | | √ | | | | √ | √ | √ |
| WR 2 | — | 0.562 | √ | | | √ | | | | √ |

* if MC 4 = A or B, then 1.06; if C or D, then 20.8
** if MC 24 = A or C, then 1.09; if B or D, then 0.40
*** NR 6 = NR 5 × 1.25
**** in any order

***Subtest***

When analyzing detailed results, please bear in mind that subtest results **cannot** be directly compared. Results are in average raw scores.

- Multiple choice and numerical response: 36.4 out of 56
- Written Response: 14.1 out of 24

| | | | | |
|---|---|---|---|---|
| GLE 1 | Quantitatively Predicting Outcomes | 21.9 | out of | 36 |
| GLE 2 | Qualitatively Analyzing Systems | 26.0 | out of | 40 |
| GLE 3 | Relationships in Energy Transfer | 14.2 | out of | 21 |
| GLE 4 | Relationships in Electron Transfer | 17.3 | out of | 31 |
| GLE 5 | Relationships in Equilibrium Systems | 7.8 | out of | 13 |
| GLE 6 | Relationships in Proton Transfer | 17.0 | out of | 26 |
| SPSC | | 18.5 | out of | 30 |
| STS | | 32.6 | out of | 54 |

**11.** Compound X has a molar mass of 75.0 g/mol. The combustion of 300.0 g of compound X causes the temperature of 1000.0 g of water to rise 3.00°C. The molar heat of combustion for compound X is

***A.** –3.14 kJ/mol

**B.** –3.77 kJ/mol

**C.** –12.6 kJ/mol

**D.** –50.3 kJ/mol

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Manufacturers used to add alum, $Al_2(SO_4)_{3(s)}$, during the production of paper. The aluminum ion was hydrated and the following equilibrium was established:

$$\underset{①}{Al(H_2O)_6^{3+}{}_{(aq)}} + \underset{②}{H_2O_{(l)}} \rightleftharpoons \underset{③}{Al(OH)(H_2O)_5^{2+}{}_{(aq)}} + \underset{④}{H_3O^+_{(aq)}} \quad K_a = 1.4 \times 10^{-5}$$

**Numerical Response**

**11.**

In the forward reaction, the Brønsted-Lowry acid is _____.
(Record your answer in the first column on the answer sheet.)

In the forward reaction, the Brønsted-Lowry base is _____.
(Record your answer in the second column on the answer sheet.)

In the reverse reaction, the Brønsted-Lowry acid is _____.
(Record your answer in the third column on the answer sheet.)

In the reverse reaction, the Brønsted-Lowry base is _____.
(Record your answer in the fourth column on the answer sheet.)

Answer: **1243**

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Treasures found in sunken Spanish galleons sometimes contain silver coins in wooden chests. After many years under water, these coins become coated through the following sequence of chemical reactions:

**I** $2\,Ag_{(s)} + H_2S_{(aq)} \rightarrow Ag_2S_{(s)} + H_{2(g)}$

**II** $CO_{2(aq)} + 2\,H_2O_{(l)} \rightleftharpoons HCO_3^-{}_{(aq)} + H_3O^+_{(aq)}$

**III** $Ca^{2+}_{(aq)} + HCO_3^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons CaCO_{3(s)} + H_3O^+_{(aq)}$

**21.** Reaction I resulted in

**A.** an increase in the pH as $H_{2(g)}$ was produced

**B.** a decrease in the pH as $H_{2(g)}$ was produced

***C.** an increase in the pH as $H_2S_{(aq)}$ was consumed

**D.** a decrease in the pH as $H_2S_{(aq)}$ was consumed

## *Multiple-Choice and Numerical-Response Questions*

The following questions were selected for discussion because they exemplify what is required to achieve, minimally, the acceptable standard and the standard of excellence.

Students just achieving the acceptable standard were capable of answering questions such as multiple-choice questions 11, 13, 15, 19, 25, 38, 40, 41, 42, and 43, and numerical-response questions 1, 2, 10, and 11. For example, in **multiple-choice question 11**, almost all students (93.4%) were able to calculate the enthalpy change of water, and most (77.3%) were able to use this to successfully determine the molar heat of combustion of compound X. The majority of students who achieved the acceptable standard (82.8%) or better (97.4%) had success on this question, while students who did not achieve the acceptable standard had limited success (42.0%). The most common error (8.4%) was in only calculating the enthalpy change of water and neglecting the amount of substance X used. This error was especially common (23.9%) among the students who did not achieve the acceptable standard.

The results from this question suggest that students who do not achieve the acceptable standard can perform routine calculations that they have memorized but do not understand what these calculations represent, and hence, are unable to solve questions that involve the blending and mixing of more than one simple calculation. While students capable of applying more than one skill or concept, such as linking routine calculations to arrive at an answer, will achieve the acceptable standard.

In **numerical-response question 11**, most of the students (77.9%) were successful in applying the Brønsted-Lowry definition of acids to analyze a chemical equilibrium of a hydrated metal ion. The majority of the students who achieved the standard of excellence (97.3%) were able to identify the Brønsted-Lowry acid and base for both the forward and reverse reactions. Students achieving just the acceptable standard (81.9%) had little difficulty in applying the Brønsted-Lowry definition of acids to this question, while students who did not achieve the acceptable standard were not very successful (48.1%). The most common error (10.1%) was in not recognizing that a reactant in the forward reaction is a product for the reverse reaction. This suggests that students capable of applying skills or concepts to an unfamiliar situation will achieve the acceptable standard.

Students just achieving the standard of excellence were capable of answering questions such as multiple-choice questions 5, 21, and 33, and numerical-response questions 4, 7, 9, and 12. For example, in **multiple-choice question 21,** as expected, almost half the students (44.7%) could not

relate pH to a weak acid in a system in equilibrium. As a result, only 40.6% of all students were successful in answering this question correctly. The most common mistake made by students was believing that a decrease in the amount of acid results in a decrease in pH. Students who achieved the standard of excellence (74.7%) were successful in answering this question, while students who achieved the acceptable standard had limited success (36.8%), and students who did not achieve the acceptable standard had very poor success (23.9%). These results suggest that students who did not achieve the standard of excellence were most likely guessing at the answer rather than applying skills or concepts. This suggests that students who achieve the standard of excellence do so because they are able to understand and integrate the concepts of equilibrium, pH, and strength.

In **numerical-response question 12**, 11.0% of the students answering the question did so correctly. Students achieving the standard of excellence (38.7%) were able to write a $K_a$ expression and substitute the given values to determine the hydronium concentration, and then, calculate the pH. Few of the students (7.0%) who achieved the acceptable standard could determine the pH. Very few of those who did not achieve the acceptable standard were able to calculate the pH (0.5%). The most common mistakes made by all students was in assuming that the concentration of the hydronium ion was equivalent to either the bicarbonate ion in a buffer (9.0%) or to the carbonic acid (12.1%). Another mistake (4.2%) they made was in assuming that the hydronium ion concentration was equivalent to the product of the carbonic acid and bicarbonate ion concentrations. The results for this question suggest that students achieving the standard of excellence understand the buffers and they are capable of combining concepts and performing multistep calculations.

An important buffer in blood is the $H_2CO_{3(aq)}$ / $HCO_3^-{}_{(aq)}$ system. The equilibrium for this buffer is

$$H_2CO_{3(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + HCO_3^-{}_{(aq)}$$

**Numerical Response**

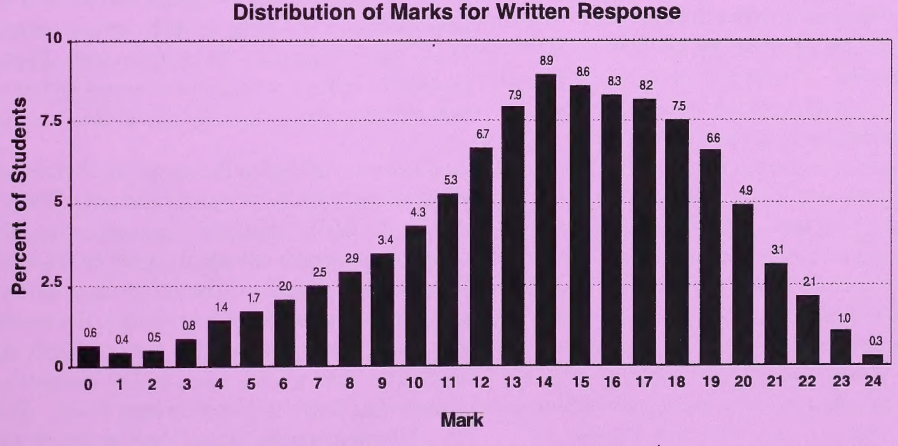
**12.** A sample of this buffer at equilibrium contains $1.1 \times 10^{-4}$ mol/L $HCO_3^-{}_{(aq)}$ and $1.2 \times 10^{-5}$ mol/L $H_2CO_{3(aq)}$. The pH of the sample is _____.

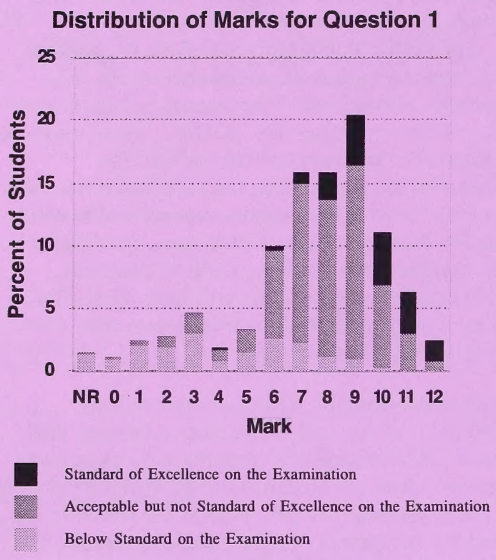
(Record your answer to three digits on the answer sheet.)

Answer: **7.32**

### *Written-Response Questions*

The level of achievement on the written-response section was as expected: almost three-quarters of the students (74.3%) achieved a mark of 12 or higher out of 24. The average mark on the written-response section was 14.1 or 58.7% of the available marks.






**Written-response question 1** was not answered as well as expected. The question was selected to measure students' ability to relate their understanding of chemistry to a real-world, Alberta context. Overall, almost every student treated the question as if it were a lab titration rather than a real issue. Most students used sodium hydroxide as the most suitable reagent to neutralize the acid. As a result, most students had difficulty in attaining full marks since it is very difficult to determine how much sodium hydroxide should be used. Very few students recognized that a weak base, such as calcium carbonate, reacts quantitatively with strong acids.

Students who did not achieve the acceptable standard were expected to score up to 6, and 75.2% did so. They averaged 4.14 by knowing that a base will neutralize an acid. The most common problems these students had was in determining what the base should be. The conjugate base of hydrochloric acid (chloride ion) was a popular choice; the other popular choice was water since it contained hydroxide that could react with the acid. These students could not write a neutralization reaction for hydrochloric acid and the base they selected. Most of these students did not address the safety of the reagents used or products produced. Most of these students' responses were poorly organized and weakly communicated. Errors in spelling, grammar, and chemical symbols were the norm.

Students who achieved the acceptable standard but not the standard of excellence on the examination were expected to score in the range of 6 to 9, and 74.1% did so. They averaged 7.78 by identifying a strong base, usually sodium hydroxide, and by writing a balanced chemical equation for the reaction between their base and hydrochloric acid. Generally, they did not consider that the addition of excess strong base poses as serious a problem as does the original acid spill. They did recognize that the formation of water would be beneficial; however, they did not recognize that a salt is also produced in neutralizations of strong acids by strong bases and that this salt could pose a danger to the environment. These students appeared careless in their use of states and ionic charges in both the text of their answer and in their chemical equations.

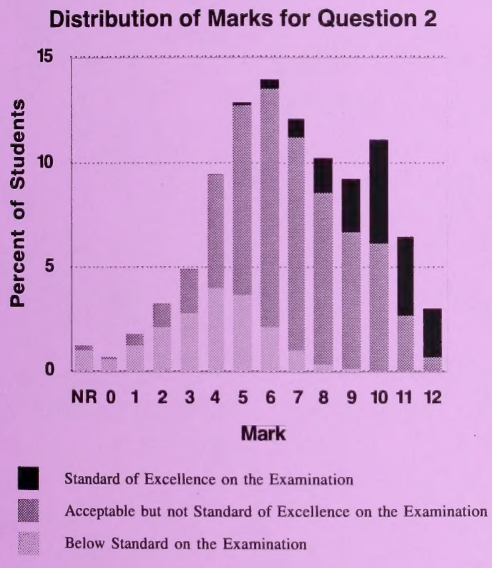
Students who achieved the standard of excellence were expected to score 10 or better, and only 55.6% did so. They averaged 9.65 by concisely communicating clear answers, writing appropriate chemical equations for the base they selected, and addressing the safety issue of the reagent they used and/or the products produced in the neutralization. The only weakness noted was that they generally selected a strong base rather than a weak base, and as a result, had difficulty in determining how much strong base to use. Most realized that the addition of excess strong base would create a major

problem, but they had difficulty in finding a practical way to monitor the addition of the strong base. Very few of the students that attained the standard of excellence recognized that the use of excess weak base, such as calcium carbonate, would neutralize the spill and produce common compounds normally found or added to the environment. Regardless of the reagent selected, these students showed good communication and organizational skills.

The results on this question suggest that most students achieving the acceptable standard are capable of selecting a reagent that will neutralize a strong acid and writing an appropriate equation for the reaction. The students who achieve the standard of excellence do so because they can select a reagent capable of neutralizing a strong acid and deal with the issue of safety of both the reagent selected and the products formed by its use.

On this 12-mark question, the average mark was 7.39 or 61.5% of the available mark.

**Written-response question 2** was answered as expected by students. The question was selected to measure students' ability to balance redox reactions that do not involve only half-reactions from their data booklet. They were not expected devise their own half-reactions in a basic medium but to use oxidation numbers to balance the equation, and most did so.


Distribution of Marks for Question 2
Percent of Students
15
10
5
0
NR 0 1 2 3 4 5 6 7 8 9 10 11 12
Mark
Standard of Excellence on the Examination
Acceptable but not Standard of Excellence on the Examination
Below Standard on the Examination

Students who did not achieve the acceptable standard were expected to score up to 5, and 80.6% met this expectation. They averaged 3.80 because they could assign oxidation numbers to some of the reagents involved, could do stoichiometry appropriate to the question, and could give a common sense safety issue for the storage and/or use of bleach. Unfortunately, they were unable to balance the given equation or calculate the molar mass of iodine, even though the formula for iodine was given in the question and the unbalanced chemical equation. They had difficulty in supporting their safety procedure since they did not focus on the potential chemical hazard of misusing/storing bleach. Several of these students recognized the chemical nature required, and selected the weak reducing agent mercury as being a suitable material for the container. Unfortunately, these students did not recognize that mercury is normally a liquid at room temperature and as itself, is a harmful substance. Another misconception held by these students is that bleach is a flammable substance and therefore must be stored in cool areas away from any ignition source. Most of these students' responses were poorly organized and contained many errors of convention. Students who achieved the acceptable standard but not the standard of excellence were expected to score from

3 3286 51077 3605

6 to 9 and scored, on average, 6.89. In total, 56.4% of these students met this expectation. They could assign oxidation numbers to all the reagents involved, perform appropriate stoichiometry — including ratios, and state a storage/handling concern. Most of these students were unable to balance the chemical equation; the few who were successful balanced by inspection rather than by oxidation numbers or by half-reactions. The most common mistake students made in balancing was not recognizing that iodine is diatomic, and as a result, assigned a "2" to the $I_{2(s)}$. Another common error these students made regarding the balancing was to use a "Hess's Law" approach to balancing the equation. They selected a series of half-reactions from the data book and attempted to add them together to yield the required reaction. Some of these students were successful at devising a balanced chemical equation; unfortunately, even though their reaction had correct reactants, they did not have correct products. Most of these students understood the need to approach the storage/handling of bleach from a chemical perspective. Most students were successful in determining that bleach should be stored in a non-reactive container and selected gold as being the most appropriate. A few did question the practicality of using gold containers. A common and deadly misconception held by these students was that a spill of bleach could be safely neutralized by the addition of an acid such as vinegar. These students' responses were generally well organized and showed some attention to detail such as significant digits and units in their calculations.

Students who achieved the standard of excellence were expected to score 10 or better and average 9.82 for this question, and 66.1% did so, with 13.9% attaining a perfect score. Students achieving the standard of excellence do so because they can successfully use oxidation numbers or create half-reactions to balance redox reactions. They have no problems in performing the stoichiometry to arrive at a correct answer. Nor do they have any problems in identifying a "real life" safety concern that was supportable by chemical principles, such strength of oxidizing and reducing agents. These students presented their answers in a concise, well-organized fashion, and expressed themselves clearly so that little, if any, interpretation was required.

The results on this question suggest that most students achieving the acceptable standard are capable of performing routine stoichiometric calculations and can balance chemical equations for redox reactions, provided the half-reactions are available to them in the data booklet. The students who achieve the standard of excellence do so because they are capable of devising their own half-reactions and are able to assign oxidation numbers for complex ions as well as simple ions. They have no problem in performing routine and complex calculations. They are also able to recognize "real-world" applications of the concepts learned in Chemistry 30.

On this 12-mark question, the average mark was 6.74 or 56.2% of the available mark.

For further information, contact Don Loerke (dloerke@edc.gov.ab.ca) or Phill Campbell (pcampbell@edc.gov.ab.ca) at the Student Evaluation Branch, at 427-0010. To call toll-free from outside of Edmonton, dial 310-0000.

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